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Increasing operational availability of H-60 calibration support equipment

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MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

Increasing Operational Availability of H-60 Calibration Support Equipment

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By: Kenneth D. Bevel,
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December 2006

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The purpose of this MBA Project was to identify inefficiencies in the H-60 support equipment calibration process at Naval Air Station, North Island and analyze their impact on operational availability. To conduct this analysis, the researchers mapped the standard calibration process at North Island from beginning to end from a using unit perspective. After identifying the process, the researchers calculated the inherent and operational availability and determined the impacts of process inefficiencies on asset operational availability. The researchers proposed changes to reduce the effects of process inefficiencies on using unit asset availability and provided guidance for further study.

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INCREASING OPERATIONAL AVAILABILITY OF H-60 CALIBRATION SUPPORT EQUIPMENT

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Submitted in partial fulfillment of the requirements for the degree of

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from the

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INCREASING THE OPERATIONAL AVAILABILITY OF H-60 CALIBRATION SUPPORT EQUIPMENT

ABSTRACT

The purpose of this MBA Project was to identify inefficiencies in the H-60 support equipment calibration process at Naval Air Station, North Island, and analyze their impact on operational availability. To conduct this analysis, the researchers mapped the standard calibration process at North Island from beginning to end from a using unit perspective. After identifying the process, the researchers calculated the inherent and operational availability and determined the impacts of process inefficiencies on asset operational availability. The researchers proposed changes to reduce the effects of process inefficiencies on using unit asset availability and provided guidance for further study.

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LIST OF ACRONYMS AND ABBREVIATIONS

AIMD	Aircraft Intermediate Maintenance Detachment
CDBF	Central Database Facility
CHMSWP	Commander of Helicopter Marine Strike Wing Pacific
COMNAVAIRFOR	Commander Naval Air Forces
COMNAVAIRFORINST	Commander Naval Air Forces Instruction
DoD	Department of Defense
DoN	Department of the Navy
ECN	Equipment Control Number
EIRT	Equipment Identification and Receipt Tag
FCA	Field Calibration Activity
HSL	Helicopter Anti Submarine Squadron
HSM	Helicopter Maritime Strike Squadron
IMA	Intermediate Maintenance Activity
LPO	Leading Petty Officer
MAGTF	Marine Air-Ground Task Force
MEASURE	Metrology Engineering Automated System for Uniform Recall and Reporting
METCAL	Metrology and Calibration
METCALREP	Metrology and Calibration Representative
METER	Metrology Equipment Recall and Report
METR	Metrology
MOCC	Measure Operational Control Center
NAMP	Naval Aviation Maintenance Program

NAS	Naval Air Station
NAVAIR	Naval Air Systems Command
NAVAIRSYSCOM	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NDCL	Naval Depot Calibration Laboratory
NIST	National Institute of Standards and Technology
NIQ	Naval Air Station, North Island Field Calibration Facility
NPSL	Navy Primary Standards Laboratory
NWSC	Naval Surface Warfare Center
OPNAV	Office of the Chief of Naval Operations
PME	Precision Measuring Equipment
SE	Support Equipment
SECNAV	Secretary of the Navy
SDB	Naval Air Rework Facility, North Island
TAMS	Test and Monitoring Systems
USMC	United States Marine Corps

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I. INTRODUCTION

A. BACKGROUND

In the past, the Calibration Industry hailed the Navy's Calibration and Metrology service as some of the most technologically advanced services rendered by the military. Over the past 60 years, the United States Navy strived to create a consistent standard for calibration in support of the Naval forces. The Navy's objectives for creating metrology and calibration standards were to increase combat readiness, reduce maintenance costs, and provide the combat forces with the most advanced support equipment that yield optimal performance and operational availability. Unfortunately, the Navy's calibration and metrology service has not updated the calibration process in order to keep pace with the technological and policy advances in the industry. While some personnel may view the Navy's calibration and metrology services as superior, other patrons at Naval Aviation Station (NAS) North Island, California, identified the calibration process as inefficient with regards to turnaround time and the operational availability of support equipment. The present challenge is to identify methods to continually improve the calibration and metrology processes to meet the needs of a changing military with shrinking resources.

The researchers initiated this project based on the work of Lieutenant Tim Snowden, USN, and Lieutenant Commander Doug Sullivan, USN, in the project titled *Filling H-60 Helicopter Readiness Shortfalls by Streamlining and Revising Depot Level Maintenance Procedures.* Following-up this project, the researchers visited the Commander of Helicopter Marine Strike Wing Pacific (CHMSWP) in March of 2006. The commander relayed his frustration towards the calibration process. His claim was that the metrology cycles for his calibration support equipment (SE) were too short. After a brief conversation, the researchers toured the calibration facilities at NAS North Island, CHMSWP's home port. During this tour, the researchers examined the calibration processes and looked for inefficient, as well as, efficient practices.

Upon further analysis, the following question emerged: Can reducing inefficiencies in the calibration process significantly increase the operational availability of SE?

B. PURPOSE

The purpose of this project was to examine the SE calibration process from the using unit perspective to discover key process inefficiencies and determine their impacts on operational availability.

C. RESEARCH QUESTION

According to Naval Aviation units at North Island, the current calibration process from the sub-custodian to the field calibration activity (FCA) and Naval Depot Calibration Laboratory (NDCL) produces inefficient results for its patrons. The questions that will be answered are: What are the key inefficiencies in the calibration process at NAS, North Island, and can improvements in these inefficiencies significantly improve the operational availability of the calibration SE?

D. SCOPE

This report focuses on the operational availability (A_o) of the calibration SE equipment for two Naval Aviation units at North Island, Helicopter Maritime Strike Squadron Forty-One (HSM-41) and Helicopter Anti Submarine Squadron Light Forty-Three (HSL-43). As defined by OPNAVINST 3000.12A, operational availability "…provides a measure of time or probability that a system's capabilities will be available for operational use when needed. The researchers analyzed the calibration process at NAS North Island and concluded that three scenarios may have a significant effect on SE operational availability.

- Early Turn-ins from the sub-custodian to the designated calibration facility.
- Late Turn-ins from the sub-custodian to the designated calibration facility.

- Delays created by entities in the calibration process from the designated calibration facility to sub-custodian.

The researchers examined each scenario to determine the effects of early turn-ins, late turn-ins, and process delays on the operational availability of support equipment. After analyzing the effects, the researchers recommended changes to improve the operational availability of SE and reduce inefficiencies in the calibration process.

E. ORGANIZATION OF STUDY

This project is six chapters. Chapter II includes a literature review of the Naval Aviation METCAL Program and the Naval Aviation Maintenance Program, as well as an explanation of the North Island Calibration Process. Chapter III outlines the various sources of the researcher's data and their respective missions in the Navy. Chapter IV presents a simplified model of the calibration process, establishes the variables the researchers utilized to express the process, outlines the scenarios that decrease the operational availability of SE, describes how the researchers prepared the data, and how the researchers applied the scenarios to the data. Chapter V provides an overview of the data, discusses trends in the overall operational availability, and analyzes specific SE inefficiencies. Chapter VI presents the conclusion, offers overall recommendations to increase the operational availability of SE, and recommends avenues of further analysis.

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II. CALIBRATION PROCESS

A. NAVAL AVIATION METROLOGY AND CALIBRATION PROGRAM

This chapter lists the Navy definitions of calibration and metrology, and also includes the purposes of the METCAL program. The researchers established this base of knowledge to provide an overview of the Navy regulations before focusing on the specific calibration process at NAS North Island.

1. Metrology and Calibration Definitions

Metrology is the science of measurement or determination of conformance to technical requirements and the development of standards and systems for absolute and relative measurements. Calibration is the process by which calibration installations compare a calibration standard or precision measuring equipment (PME) with a standard of higher accuracy to ensure the former is within specified limits throughout its entire range. (Department of the Navy [DoN], COMNAVAIRFORINST 4790.2, 2005) The Navy uses metrology to determine the adequate technical requirements for a system and then uses calibration to measure those technical requirements against a system of unknown accuracy. The quantitative measurements allow SE to operate safely and efficiently within the established tolerances noted in NAVAIR 17-35MTL-1.

2. Metrology and Calibration Program (METCAL)

The Secretary of the Navy (SECNAV) established the METCAL Program to support the Navy's metrology and calibration requirements. The METCAL Program provides the operating forces the calibration and repair facilities that ensure optimum performance of calibrated SE. (DoN, N88-NTSP-A-50-8701B/A, 2000) The calibration facilities compare the SE to metrology standards of higher accuracy to create uniform and traceable measurements with links to the National Institute of Standards and Technology (NIST), the U.S. Naval Observatory, or another Department of Defense (DoD) approved calibration facility. The primary technical authority for the METCAL Program is the

Measurement Science Department at the Naval Surface Warfare Center (NSWC) in Corona, California. The core functions of the Measurement Science Department are the following:

- Provide Navy-wide technical direction, support, and guidance relating to measurement requirements for Test and Monitoring Systems (TAMS) to Naval Sea Systems Command (NAVSEA), Naval Air Systems Command (NAVAIR), Strategic Systems Program, and Marine Corps Metrology and Acquisitions Program Offices. (DoN, Naval Surface Warfare Center [NWSC], 2006)
- Evaluate measurement and calibration requirements for a wide range of Navy programs and systems, both domestic and Foreign Military Sales. (DoN, NWSC, 2006)
- Establish, document, and sustain Navy calibration support requirements including test parameters, required calibration equipment, support documentation, servicing intervals, logistic support levels, and calibration training requirements. (DoN, NWSC, 2006)
- Perform engineering studies and analyses to assure that measurement traceability requirements are achieved. (DoN, NWSC, 2006)
- Provide technical guidance, review, and approval to Navy activities and contractors in the development of Integrated Logistics Support Plans, Life-Cycle Support Planning, calibration source data, and similar documents related to the Navy METCAL Program. (DoN, NWSC, 2006)

While NWSC provides guidance and instruction for calibration and metrology services, NAVAIR 17-35NCA-1 delineates which level of calibration facility will conduct the calibration and repair of each type of support equipment. The three calibration levels that support Naval calibration activities.

a. Navy Primary Standards Laboratory (NPSL)

NPSL is the Fleet Support Activity for calibration standards. NPSL maintains direct liaison with NIST and the Naval Observatory to ensure measurements are traceable. The purpose of NPSL is to provide critical metrology engineering services for support equipment and TAMS outside the capabilities of lower echelon calibration laboratories, and supply as a repository for Navy primary standards (DoN, N88-NTSP-A-50-8701B/A, 2000).

b. Navy Depot Calibration Laboratory (NDCL)

NDCL provides calibration and repair of metrology standards and SE that are beyond the capability of lower echelon calibration laboratories. The National Bureau of Standards, via NPSL, provides the calibration and metrology repair standards to NDCL. (DoN, N88-NTSP-A-50-8701B/A, 2000) The NDCL also provides ashore and afloat calibration services to NAVAIRSYSCOM.

c. Field Calibration Activities (FCA)

Combining both afloat and ashore numbers, the Navy operates approximately 100 Intermediate Maintenance Activities (IMAs). (DoN, N88-NTSP-A-50-8701B/A, 2000) Within the IMAs, the Navy established and designated Work Centers 67A, and designated calibration laboratories as FCAs. Military personnel, versus civilian, primarily operate the FCAs. Their mission is to provide intermediate level calibration and repairs of any fleet SE and metrology standards for which they maintain standards and instrument calibration procedures. (DoN, N88-NTSP-A-50-8701B/A, 2000)

The three levels of calibration facilities work together to provide customers with current calibration requirements and use the latest tools and technology to increase equipment readiness and reduced maintenance cost.

The METCAL program assigns each asset a laboratory code. That specific laboratory is responsible for conducting the calibration and repair of that asset. One goal of the METCAL program is to support the concept of "calibrating at the lowest level possible." (DoN, COMNAVAIRFORINST 4790.2, 2005) This concept allows simple calibrations to remain at the lower levels of maintenance, while allowing the higher echelons of maintenance to focus on more critical or complex calibration requirements.

B. NAVAL AVIATION CALIBRATION

The Commander Naval Air Forces (COMNAVAIRFOR) outlined the use of the calibration program in the Naval Aviation Maintenance Program (NAMP) manual to support the Navy's metrology and calibration goals. The purpose of COMNAVAIRFOR's directives is to coordinate the proper use of the METCAL program at the organizational, intermediate and depot level maintenance. "The objective of the NAMP is to achieve and continually improve aviation material readiness and safety standards established by the Chief of Naval Operations and COMNAVAIRFOR, with coordination from the Commandant of the Marine Corps focusing on the optimal use of manpower, material, facilities and funds." (DoN, COMNAVAIRFORINST 4790.2, 2005) The NAMP outlines the responsibilities, policies and requirements for the three levels of maintenance as they relate to metrology and calibration. The purpose for outlining the procedures is to guarantee uniform, relevant, and traceable calibration processes.

C. NORTH ISLAND CALIBRATION PROCESS

The calibration facilities at NAS North Island have the capability to provide intermediate and depot level calibration. For the purpose of this project, the researchers focused on the calibration procedures from the sub-custodian to the intermediate and depot-level calibration facilities. In the following sub-sections, the researchers outlined the responsibilities of each entity in the calibration process. These responsibilities provide more clarity to the overall calibration process.

a. Sub-Custodian Calibration Process Responsibilities

The sub-custodian, as defined by the NAMP manual, is "…a MEASURE participant supported by a customer activity that has physical custody of equipment, regardless of actual ownership." (DoN, COMNAVAIRFORINST 4790.2, 2005) According to the calibration process at NAS North Island, HSM-41 and HSL-43 are sub-custodians. The sub-custodian's calibration responsibilities begin with the acceptance of MEASURE format 802. (See Appendix B) According to the MEASURE users manual (OPNAV OP43P6B), the sub-custodian retrieves the MEASURE recall format 802 from

the Wing METCAL Representative. Once the sub-custodian identifies the SE required for calibration per recall format 802, it prepares them for pick-up. Work Center 67A, which is a sub-department of the IMA, picks up the equipment. The 67A personnel give a copy of the Equipment Identification and Receipt Tag (EIRT) to the sub-custodian and then transfer the equipment to the appropriate calibration facility. (DoN, COMNAVAIRFORINST 4790.2, 2005)

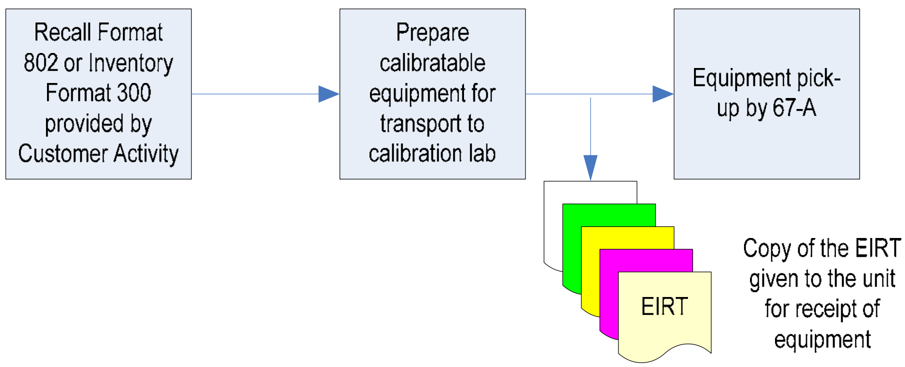

Figure 1. Calibration Process at the Sub-Custodian Level

b. Customer Activity Calibration Process Responsibilities

The Customer Activity, as defined by the NAMP manual, is "…a MEASURE participant that coordinates the servicing and calibration of PME/TAMS within a specific area." (DoN, COMNAVAIRFORINST 4790.2, 2005) For the scope of this project, the Aircraft Intermediate Maintenance Detachment (AIMD), North Island, is the Customer Activity. The AIMD's primary responsibilities in the calibration process are to monitor intermediate and depot-level workflow from the squadrons, maintain documentation of calibration activities, and obtain paperwork for calibration procedures. Additionally, the Customer Activity receives pre-printed Metrology Equipment Recall and Report (METER) cards from the MOCC and prepares the EIRT cards for SE turn-in and receipt.

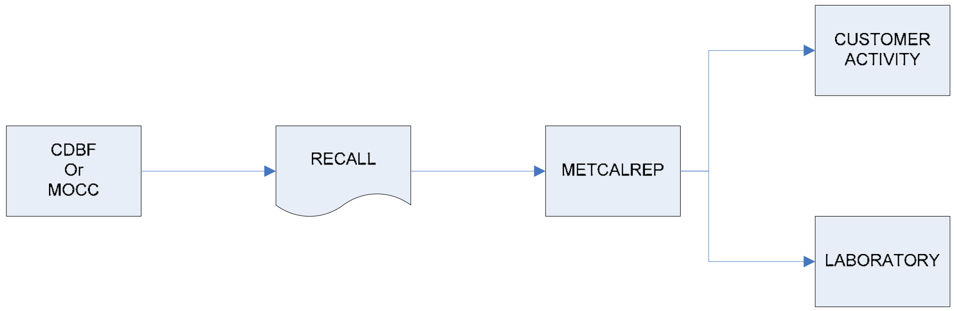

Figure 2. MEASURE Recall Process (DoN, OPNAV OP43P6B, n.d.)

As previously described, Work Center 67A provides a driver and transportation to pick-up the SE from each squadron. Once the 67A personnel pick up the SE, they attach the METER and EIRT cards to the equipment and transport the equipment and cards to the designated calibration facility. After the calibration facility calibrates the SE, the 67A personnel retrieve the equipment and return it directly to the sub-custodian. The following figure illustrates the Calibration Process from the Sub-Custodian to the NDCL or FCA.

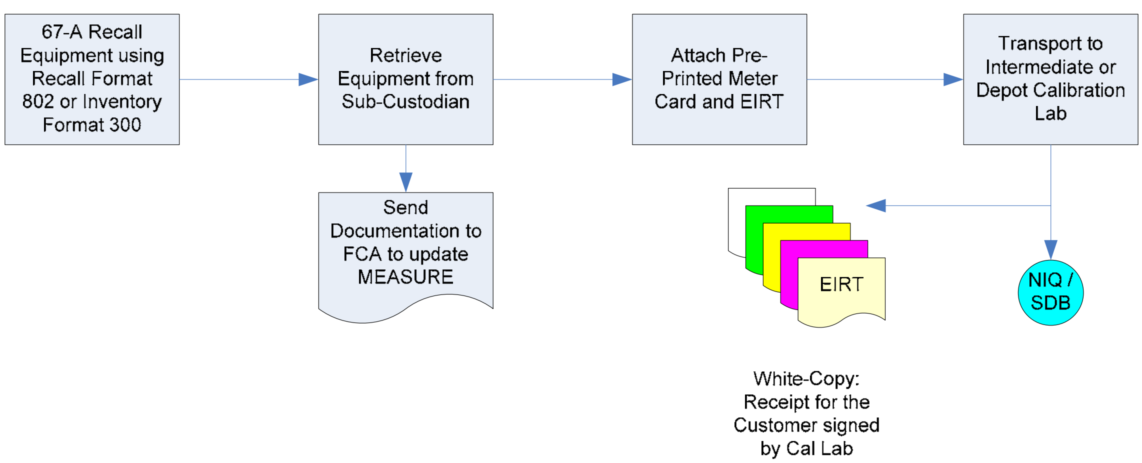

Figure 3. Calibration Process from the Sub-Custodian to the NDCL or FCA

c. Calibration Facility Responsibilities

The Calibration Facility, as defined by the NAMP manual, is "…an installation under the control of military departments or any agency of DoD." (DoN, COMNAVAIRFORINST 4790.2, 2005) It provides calibration services for PME and calibration standards used by activities engaged in the following activities:

- Research
- Development
- Test and Evaluation
- Production
- Quality Assurance
- Maintenance
- Supply
- The Operation of weapons system(s), equipment, and other DoD material. (DoN, COMNAVAIRFORINST 4790.2, 2005)

For this project, the researchers investigated the calibration services provided by the FCA and the NDCL at NAS North Island. As previously mentioned, the FCA is an intermediate-level calibration facility that provides calibration services to MEASURE participants. NAS North Island's FCA (listed as "NAS North Island" in NAVAIR 12-35NCA-1) conducts calibration activities for the sub-custodians and oversees the establishment of a PME/TAMS production control work center (67A). Additionally, the facility controls the flow of calibration equipment from the sub-custodians to the intermediate and depot-level calibration facilities. (DoN, COMNAVAIRFORINST 4790.2, 2005) The NDCL is a depot-level calibration facility that provides metrology and calibration services to MEASURE participants. For North Island, the depot level calibration facility is Naval Air Rework Facility (NAVAIREWORK), which conducts calibration and metrology services for units afloat and ashore. According to NAVAIR 17-35NCA-1, the laboratory code for NAS North Island is NIQ and the laboratory code for NAVAIREWORK is SDB.

SDB and NIQ have similar roles in the calibration process at NAS North Island. At this point, 67A brings the SE to the shipping and receiving area of NIQ or

SDB. After receipting for the item, support personnel assign the item to a shelf location and annotate the location on the METER card and the EIRT card. When an artisan is available to work on the SE, the Leading Petty Officer (LPO) or civilian supervisor selects the equipment from the shelf and verifies the METER and EIRT cards for accurate administrative annotations and uniformity. Once the civilian supervisor or LPO views the paperwork, the production supervisors issue the equipment and the EIRT card to the technician for calibration, while retaining the METER card on file. After the technician calibrates the equipment and checks it for quality assurance, he returns the item to the central calibration receiving point for pick-up by 67A personnel. Following the calibration procedures at the FCA/NDCL, the 67A personnel return the equipment to the sub-custodian completing the process. Figure 3 illustrates the process.

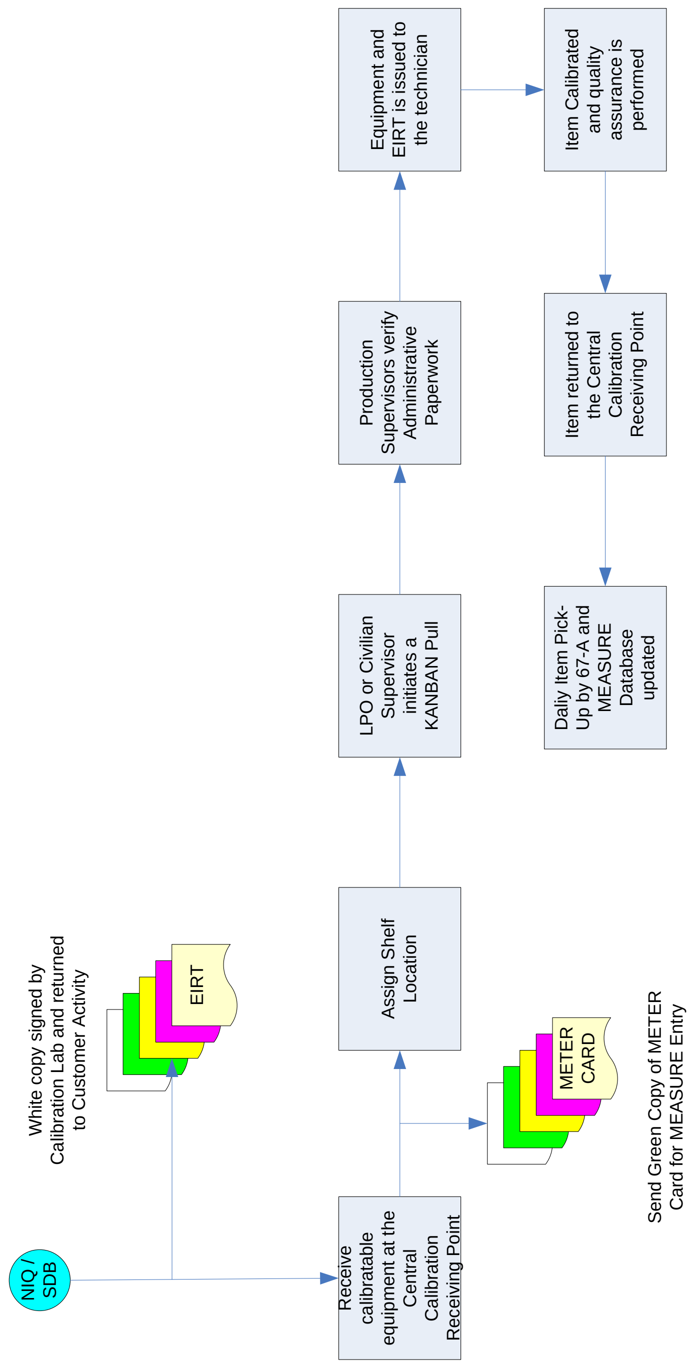

Figure 4. Calibration Process at the Calibration Facility

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III. DATA SOURCING

A. DATA FROM MOCC

A representative from the MOCC NAS, North Island provided the researchers with the MEASURE data from HSM-41 and HSL-43 in the form of an excel spreadsheet. The data covered the period from March 1998 through May 2006. The researchers sequentially narrowed the fields of data within the excel file to view only the datum relevant to the SE calibration process. The researchers will discuss a detailed description of MEASURE in Section D of this chapter.

B. DATA FROM THE SQUADRONS

HSM-41 and HSL-43 are SH-60/MH-60R Helicopter Squadrons located at NAS, North Island. The researchers randomly selected both squadrons. The mission of HSM-41 is "To train Naval aviators and Naval aircrew personnel to employ the SH-60B and MH-60R aircraft in conducting offensive and defensive anti-submarine and surface warfare operations in littoral regions and at sea, in a high-density, multi-threat environment." (Helicopter Maritime Strike Squadron Forty-One [HSM-41], 2006) The mission of HSL-43 is to "Qualify, train, and deploy fully combat-ready detachments onboard U.S. warships. (Helicopter Anti Submarine Squadron Light Forty-Three [HSL-43], 2006) When ashore at North Island, both HSL-43 and HSM-41 follow the same calibration asset turn-in/receipt process as described in Chapter II. Each squadron utilizes the same type of Recall Schedule that the MOCC provides. The researchers describe the Recall Schedule in Section F of this chapter.

Along with the MEASURE data the researchers received from the MOCC, HSM-41 and HSL-43 each provided data illustrating the 10 most often broken SE as well as the 20 most often utilized SE. In Chapter IV, the researchers applied the results from various operational availability analyses to this set of data to illustrate the specific impacts that early and late turn-ins have on the operational availability of these equipments.

C. MOCC DESCRIPTION

The MOCC operates as a Government Owned Contractor Operated activity, and provides several services to METCAL customers. First and foremost, MOCC personnel operate the MEASURE program, which ultimately aides the sub-custodians in the schedule and recall of their SE. The MOCC maintains current and accurate data and process methodologies. By maintaining updated Information Technology, the MOCC provides the sub-custodian an efficient and cost-effective means of reaching mission objectives. MOCC personnel work hand-in-hand with the METCAL representatives to manage and oversee the calibration process among the units stationed at NAS, North Island. (MOCC, personal communication, October 4, 2006)

D. MOCC CALIBRATION PROCESS RESPONSIBILITIES

The initial process for a using unit to establish documentation into MEASURE begins with the completion of inventory forms containing all calibration assets owned by the Customer Activity that will enter the calibration process. The appropriate Metrology Calibration Representative (METCALREP) verifies these forms and then forwards the documents to the appropriate MOCC, or Central Database Facility (CDBF) if a MOCC is not available, for documentation into MEASURE. The Customer Activity receives a printed inventory along with the preprinted METER cards that accompany the calibration asset during the turn-in phase of the calibration process. The METCALREP initiates the last stage of the initial MEASURE Inventory Cycle by providing the Customer Activity and Calibration Activity/Laboratory with a one month projected Recall Schedule of calibration assets due in for calibration. Figure 2-1 illustrates this process. (DoN, OPNAV OP43P6B, n.d.)

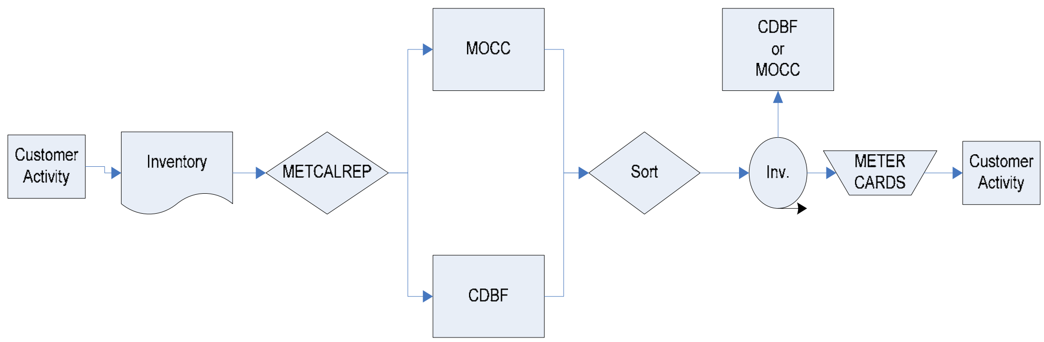

Figure 5. MEASURE Inventory Cycle

E. MEASURE DESCRIPTION

MEASURE is a system designed to:

> …provide participating activities with a standardized system for the recall and scheduling of metrology assets into Calibration Laboratories/Activities, and documentation of data pertaining to calibration actions and related transactions performed by those Calibration Laboratories/Activities, as well as for reporting all actions performed on those equipments. (DoN, OPNAV OP43P6B, n.d.)

MEASURE tracks data on the collection, correction, analysis and collation of technical data, as well as distribution of data and products/formats to requiring Calibration Laboratories/Activities and Customer Activities. (DoN, OPNAV OP43P6B, n.d.) In addition, MEASURE supports the following functions:

- Develop and support Navy METCAL Program resource budgets. (DoN, OPNAV OP43P6B, n.d.)
- Plan/analyze Calibration Laboratory/Activity workload. (DoN, OPNAV OP43P6B, n.d.)
- Record/document configuration changes and update data base files. (DoN, OPNAV OP43P6B, n.d.)
- Provide technical data to the Metrology Engineering Center for Test and Monitoring Systems (TAMS) reliability, analysis and calibration interval assignment (DoN, OPNAV OP43P6B, n.d.)
- Document traceability of measurements to standards maintained by the National Institute of Standards and Technology (formerly National Bureau of Standards). (DoN, OPNAV OP43P6B, n.d.)

Simply stated, the MEASURE system provides MEASURE participants with an accurate picture of the SE calibration process as well as useful historical data for future analysis.

IV. METHODOLOGY

A. OVERVIEW

Beyond the anecdotal stories, the researchers needed to find data that could clarify whether or not the calibration process contained inefficient practices. Through the use of the MEASURE data as well as the descriptions from the key parties involved, the researchers created a simplified process flow chart illustrating the standard calibration process at SDB or NIQ. Appendix C illustrates this simplified process.

B. KEY MEASURE ENTRIES

The following bullets list the key MEASURE time entries the researchers utilized to track the calibration process. Appendix C illustrates where each time entry occurs in the calibration process.

- DT_RCVD – This entry denotes the date the Calibration Laboratory/Activity received the SE from 67A personnel. (DoN, OPNAV OP43P6B, n.d.)
- DT_INDCT – This entry denotes the date the artisan at the Calibration Laboratory/Activity initiated work on the equipment and inducted it into the calibration maintenance cycle. (DoN, OPNAV OP43P6B, n.d.)
- DT_CMPL – This entry denotes the date the artisan at the Calibration Laboratory/Activity completed work on the equipment and returned it to the receiving area for out-processing. (DoN, OPNAV OP43P6B, n.d.)
- DT_PROC – This entry denotes the date 67A personnel retrieved the asset from the Calibration Laboratory/Activity. (MOCC, personal communication, October 16, 2006)
- DT_NXTDUE – This is the date equipment is due to return to the facility for a subsequent calibration. MEASURE automatically enters this date based on the metrology cycle and the date the artisan completed working on the asset (DT_CMPL). (DoN, OPNAV OP43P6B, n.d.)

C. ESTABLISHING THE FIVE VARIBLES USED TO EXPRESS THE CALIBRATION PROCESS

After analyzing the standard calibration procedures, the researchers established five variables to express different elements in calibration process. Appendix C illustrates the order and duration of each variable in the process

1. The Variable X

The variable X represents the Metrology (METR) cycle for the SE. The METR cycle is the number of days the end user may utilize the equipment after an approved calibration laboratory/activity verifies the standard of calibration. In the researcher's data, the length of the METR cycles ranged from 3 to 60 months, with a mean of 15.7 months and a mode of 12 months.

2. The Variable Y

The variable Y represents the average value added calibration process time. It begins when an artisan inducts the SE into the calibration process and ends when an artisan finishes all work on the equipment and establishes a new METR cycle. In this project, the researchers assumed that the duration an artisan works on SE is value added time. In the researcher's data, the length of the process times ranged from 0 to 253 days, with a mean of 6.52 days and a mode of 0 days.

3. The Variable V

The variable V represents the delay that occurs after a using unit releases the SE into the calibration cycle, but before an artisan inducts the equipment into maintenance. In the researcher's data, the length of these delays ranged from 1 to 161 days, with a mean of 4.85 days and a mode of 1 day.

4. The Variable W

The variable W represents the delay that occurs from when the artisan completes calibration on the SE (establishing a new METR cycle), to when the using unit regains

custody of the equipment. In the researcher's data, the length of these delays ranged from 1 to 111 days with a mean of 4.22 days and a mode of 2 days.

5. The Variable Z

The variable Z represents the number of days the using unit releases the equipment from their custody either before or after the expiration of the METR cycle. In the researchers' data, the values of this variable ranged from 1,088 days early (or -1,088) to 1,472 days late. While the average value of Z for the researcher's data was -87 days, or 87 days early, the average deviation from zero (the average absolute value of Z) was 107 days. The mode for this variable was -1, or 1 day early. Once again, Appendix C provides a visual overview of the calibration cycle and also portrays the scope of each of the previously described variables.

D. SCENARIOS DECREASING OPERATIONAL AVAILABILITY

The underlying problem in the calibration process is the variability in the turn in of the SE. When the Navy first procured the equipment, it designed a standard operational availability based on the prescribed metrology cycles for each type of SE. Unfortunately, when equipment arrives early or late to the calibration facility, the operational availability of that equipment decreases. Additionally, the availability decreases for every delay that the equipment experiences in its return trip to the squadron. These three types of inefficiencies amount to all of the possible ways a using unit can reduce equipment operational availability. In the following sub-sections, the researchers will use the five variables outlined in the previous section to express the three possible reductions in operational availability.

1. Inherent Availability Scenario

The following equation represents the Inherent Availability (A_i) for the process. The A_i equation includes the available useful equipment time and the value-added

maintenance functions and excludes administrative and logistics functions. (DoN, OPNAVINST 3000.12A, 2003) As described earlier, X equals the METR cycle for the SE, Y equals the average process time. Assuming V, W, and Z equal zero, the operational availability is as follows:

$$A_i = \frac{X}{X+Y}$$

Equation 1. Inherent Availability

The following equation represents a numerical example of the A_i. Assuming a base scenario of a 3-month or 90-day METR cycle (X) and a 10-day maintenance process (Y), the A_i is as follows:

$$A_i = \frac{90}{90+10} = 0.9$$

Equation 2. Numerical Example of A_i

The resulting A_i is 90%.

2. Early Asset Turn-in

The squadrons turn in SE to the Calibration Laboratory/Activity early when they suspect the equipment is out of calibration standards. The researchers identified three general scenarios when the squadrons suspect the SE is out of standard and turn the equipment in early for calibration. The first scenarios are due to "technicalities," like if the calibration sticker located on the SE becomes illegible or detaches before the end of the METR cycle. The information on the calibration sticker is pertinent to the accurate use of the SE, and if it becomes illegible, Navy regulations require the using units to re-calibrate the equipment, even though the equipment's current METR

cycle has not expired. These situations usually result over a long period of time, and with SE that the using unit uses frequently.

The second scenarios result when the using unit physically shocks the equipment, or compromises calibration seals. Once again, the Navy requires the using unit to re-calibrate the equipment because such actions could easily affect the SE's calibration settings. These scenarios often occur when the using unit personnel accidentally drop the equipment. Although the previous scenarios require the using units to turn in the equipment early, these scenarios account for a small percentage of the early turn-ins. Most early turn-ins arise from a third scenario.

The third scenarios arise when the using units turn-in the SE early on their own volition. Examples of these scenarios include when using units want the equipment to start a deployment cycle with a new calibration, or to renew the calibration on equipment the using units infrequently use. (METCAL Rep, personal communication, November 6, 2006)

The following equation represents a scenario where a using unit turns in SE to the Calibration Laboratory/Activity early, before the expiration of the METR cycle.

$$A_o = \frac{X - Z - W}{X - Z + Y + V}$$

Equation 3. Early Turn-in Operational Availability

As before, X equals the METR cycle and Y equals the value added time at the Calibration Laboratory/Activity. In this scenario, the variable V equals the delay processing the SE to the Calibration Laboratory/Activity, the variable W equals delay returning the SE to the using unit following calibration, and variable Z equals the number of days the squadron turns the SE in early, before the expiration of the METR cycle. The researchers subtract the value of Z from X in the numerator and the denominator because the using unit looses these days from the METR cycle and the entire cycle as a whole. The maintenance process days in "Y" remain the same in the equation. An example of

this scenario would be a unit re-establishing the METR cycle for tools prior to deployment by turning the asset in “Z” days before the METR cycle expired.

Assume the same base scenario values from the previous numerical example, where X is a 90-day METR cycle and Y is a 10-day maintenance cycle. For simplicity, assume the variables W and V are zero. Assuming a Z value of 5 days, i.e., a scenario where the squadron enters the SE into the cycle 5 days before the expiration of the METR cycle, the resulting operational availability is as follows:

$$A_o = \frac{90-5-0}{90-5+10+0} = .895$$

Equation 4. Numerical Example of Early Turn-in Operational Availability

The resulting A_o is 89.5% operational availability.

3. Late Asset Turn-in

The squadrons turn-in SE late for several reasons. The first scenarios result from administrative oversight. Using unit personnel simply forget to turn in the equipment on time. The operational tempo plays a factor in this situation. The next scenarios result when using units turn in equipment late because they wait until after returning from deployment. The using units could turn in the equipment aboard ship for calibration, but choose to hold on to the equipment until the ship returns to home port. The next scenarios are also related to deployments. Errors in tracking account for late turn-ins as well. Currently, the MOCC sends calibration reports to deployed using units via physical mail. These reports show dates the SE is due for calibration. Sometimes, the mail process delays or losses these reports. The last scenarios arise from the transfer of equipment between the homeguard squadrons and their deploying detachments. Currently, the homeguard squadrons do not have visibility of the SE once they transfer it to the deploying detachment. The loss of visibility could result in inefficient turn-in processes.

The following equation represents late turn-in, or a scenario where a squadron enters SE into the calibration process several days after the equipment's METR cycle expires. An example of this scenario would be if a mechanic neglected a tool in the shop bench until the next time he needed it. At that time, he realized that the equipment needed to be recalibrated and entered it into the calibration cycle. The resulting equation would look like the following:

$$A_o = \frac{X - W}{X + Y + V + Z}$$

Equation 5. Late Turn-In Operational Availability

In this scenario, the using unit uses the tool for the full METR cycle, so the value of X does not decrease as in the early turn-in example. Instead, the using unit adds additional time onto the cycle by maintaining possession of the equipment following the expiration of the METR cycle. Unlike the previous scenario (Early Turn-in), the numerator does not change by the value of X like the denominator. The reason for this difference is as follows: Although the using unit increases the overall process cycle by Z days when it maintains possession beyond the METR cycle length, Navy regulations stipulate it cannot use the asset beyond the expiration of the METR cycle. Assuming the base scenario values for X and Y, V and W equal to zero, and a Z equal to a 5 day delay, the operational availability equation would look like the following:

$$A_o = \frac{90 - 0}{90 + 10 + 5 + 0} = .857$$

Equation 6. Numerical Example of Late Turn-In Operational Availability

The resulting A_o is 85.7% operational availability.

4. Comparing Early versus Late Equipment Turn-ins

The following figure displays the relative impact of early and late equipment turn-ins on operational availability, given the same values of X, Y, V, and W.

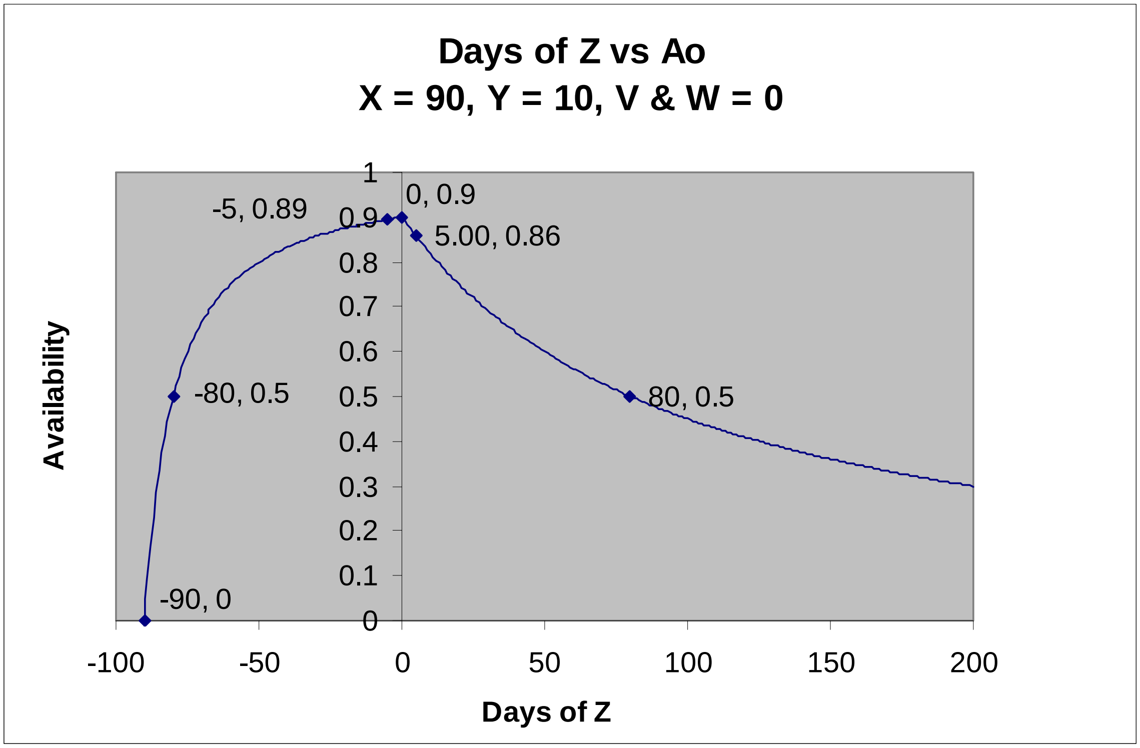

Figure 6. Graph of A_o with Changing Values of Z

As the reader can see, the different equations for early and late equipment turn-ins result in a graph of operational availability that is different about the y-axis.

5. Delayed Delivery to the Using Unit

The final scenario that decreases operational availability is the delay returning the equipment to the unit following calibration.

Given our base scenario, with the delay marked as W, the equation would look like the following:

$$A_o = \frac{X - W}{X + Y + V + Z}$$

Equation 7. Delayed Delivery Operational Availability

In this case, these delays deplete the numerator but not the denominator because the equipment must still wait X days from being calibrated before it can enter the maintenance cycle to be re-calibrated. Using the same base scenario numbers and assuming W equals 5, V equals 0, Z equals 0, the following equation results:

$$A_o = \frac{90 - 5}{90 + 10 + 0 + 0} = 0.85$$

Equation 8. Numerical Example of Delayed Delivery Operational Availability

The resulting A_o is 85% operational availability.

The following figure depicts the impact delays have on operational availability, when the delay occurs following the calibration of the equipment.

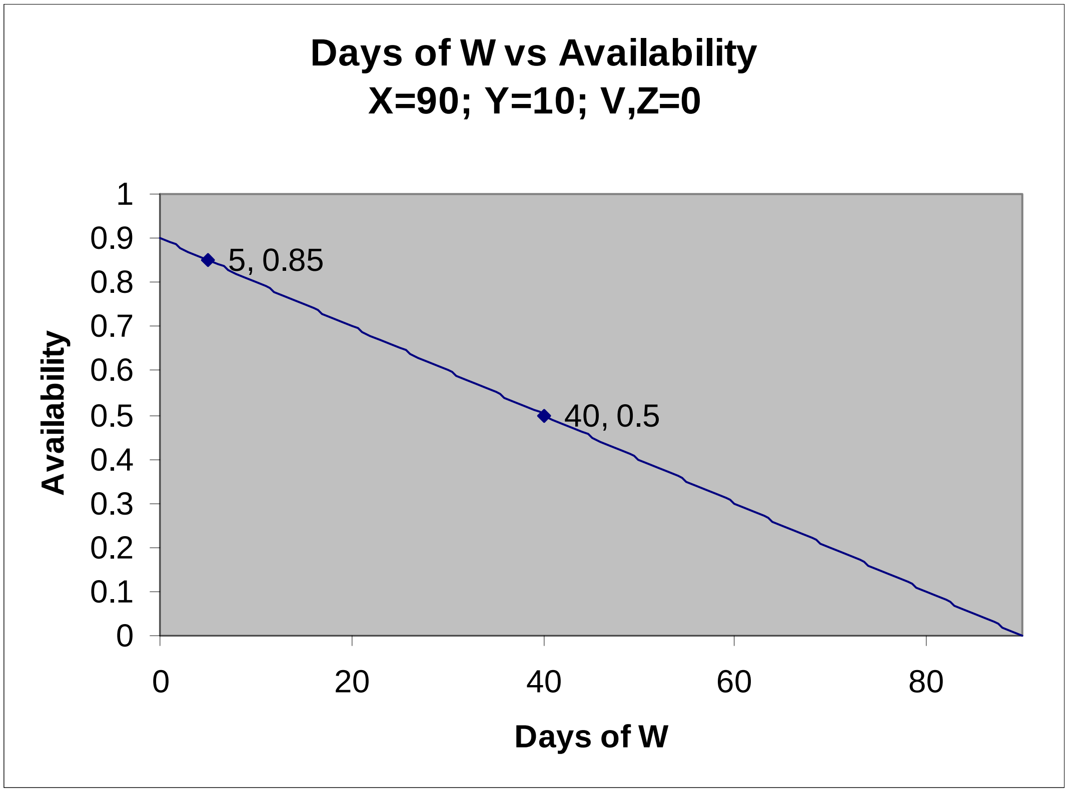

Figure 7. Graph of A_o with Increasing Values of W

As the graph depicts, increases in the value of W result in a linearly decreasing graph of operational availability.

6. Increases in the Processes of Y and V

Due to their statistical insignificance, the researchers did not investigate inefficiencies in the process represented by the variables Y and V. Due to the nature of the availability equations, the changes in the variables Y and V have the same affect on operational availability. The following figure shows the affect of increasing values of Y or V on operational availability.

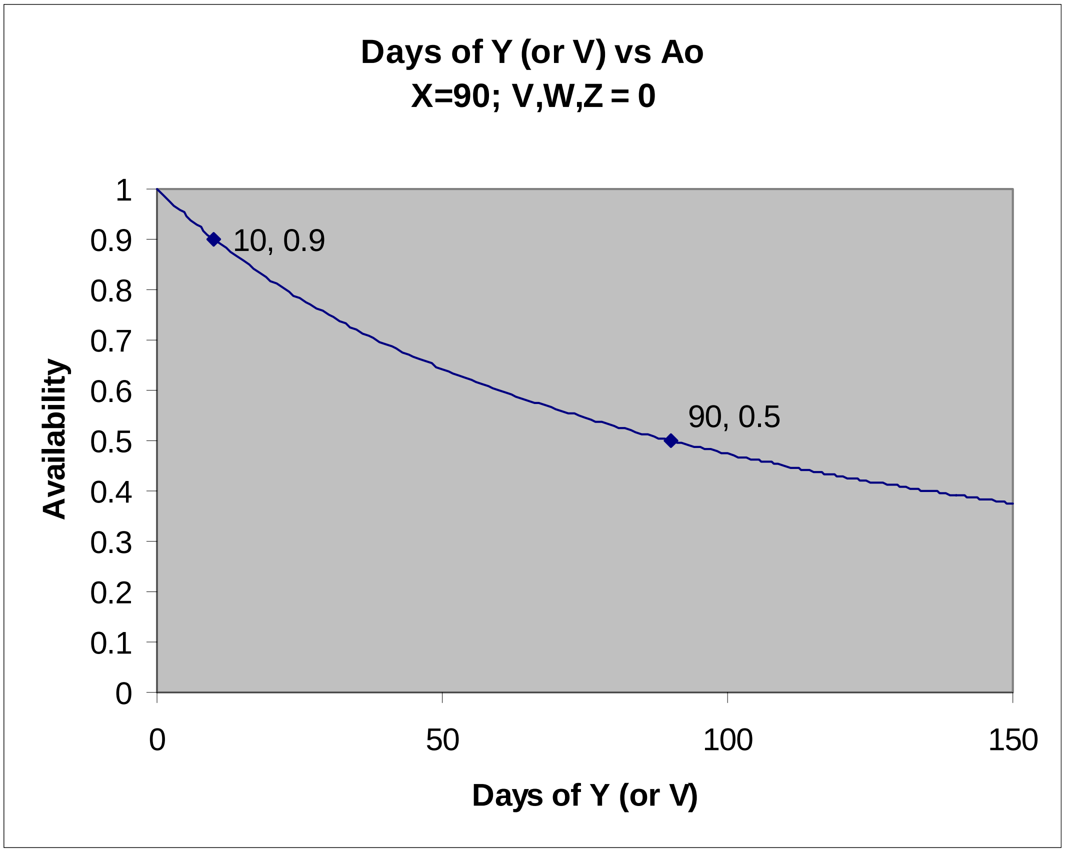

Figure 8. Graph of A_o with Increasing Values of the Variables Y or V

Increases in the value of Y or V have the same affect on operational availability as late turn-in values for Z.

E. DATA PREPARATION

The data the researchers received from the MOCC comprise 8,644 line entries for all of the SE both HSM-41 and HSL-43 turned in between March 1998 to May 2006. Each line contains multiple columns of datum detailing the specific identity of each piece of equipment, the actions taken to service the equipment, the key dates detailing the custody transfers, and the work processes and times for the equipment. The researchers first step was to organize and refine the data by "scrubbing" the data to eliminate lines unnecessary in the scope of the research.

1. Scrubbing and Sorting the MEASURE Data

As previously stated, the data comprised the 8,644 records input into the MEASURE system for HSM-41 and HSL-43 from March 1998 to May 2006. The researchers used the below processes to eliminate extraneous lines from the unrefined data.

a. Eliminating Administrative Lines

As mentioned, the data contained administrative entries. These entries reflected administrative changes in the MEASURE system, but represented no actual work performance on equipment. An example of such an administrative entry might be the change in the nomenclature of a tool. Such a change would result in an administrative entry into MEASURE for every serial number of the affected tool in the system. Through consulting with the MOCC personnel, the researchers identified these cases when the calibrating facility spent no hours calibrating, repairing, or modifying the equipment. The researchers identified 5,210 such lines of data and eliminated them from the database. The net total lines of data decreased from 8,644 to 3,434.

b. Sorting the Data

The researchers sorted the 3,434 lines of data first by model (the specific type of SE), then by equipment control number (ECN), which is specific to each serial number of each model, and finally, in chronological order by the date the equipment arrived (DT_RCVD) at the Calibration Laboratory/Activity.

2. Defining the Variables X, Y, V, W, and Z in the MEASURE Data

The researchers used a standard method to determine the values of X, Y, V, W, and Z across all of the records of data. The following sub-sections outline how the researchers calculated the values of these variables.

a. The Value of X

The researchers determined the value of X by subtracting the date the item was due for calibration in the previous cycle from the date the artisan completed working on the SE in the current cycle (DT_NXTDUE[of previous cycle] - DT_CMPL). The

researchers used this method of determining X because it provided a precise number of days and thus greater accuracy versus multiplying the METR cycle value by 30 days. Using this process, a 6-month METR cycle equals anywhere from 178 to 184 days long, depending on which months the cycle spans. Additionally, some SE received a special calibration that is longer or shorter than the METR cycle. This method correctly calculates these non-typical METR lengths.

b. The Value of Y

The researchers determined the value of Y by subtracting the difference between the date the artisan inducted the equipment into maintenance cycle and the date an artisan competed calibration on the equipment (DT_CMPL - DT_INDUCT). The result equaled the number of days an artisan worked on the SE, or more accurately, the number of days the artisan had possession of the equipment. As a reminder, the researchers assumed there was no wasted time between when an artisan inducted the SE into maintenance and when he completed the maintenance. For example, if an artisan inducted a tool on 4 March 2005 and completed working on the tool on 18 March 2005, Y is 14 days of value added time.

c. The Value of V

The researchers determined the value of V by calculating the number of days the calibration facility needed to induct the SE into maintenance following its arrival at the facility, plus the estimated number of days 67A needed to transfer the SE from the using unit to the facility. Once again, since there are no records tracking the amount of time 67A requires to transfer a piece of equipment from the using unit to the Calibration Laboratory/Activity, the researchers contacted 67A and obtained an estimated value of 1 day for this time. The researchers calculated the number of days the Calibration Laboratory/Activity needed to induct the equipment into maintenance by subtracting the difference between the date the Calibration Laboratory/Activity inducted the equipment into MEASURE and the date the Calibration Laboratory/Activity received the equipment, plus 1 day for transfer by 67A (DT_INDUCT - DT_RCVD + 1).

d. The Value of W

The researchers determined the value of W using the number of days the equipment needed to exit the Calibration Laboratory/Activity following completion of all work, and adding that value to the estimated number of days 67A needed to transfer the equipment to the using unit. Once again, since there are no records tracking the amount of time 67A needs to transfer SE from the Calibration Laboratory/Activity to the using unit, the researchers contacted 67A and obtained an estimated value of 1 day for this time. The researchers calculated the number of days equipment needed to leave the Calibration Laboratory/Activity by subtracting the difference between the date the Calibration Laboratory/Activity processed the equipment into MEASURE and the date the artisan completed work on the equipment, plus 1 day for the transfer by 67A (DT_PROCSD - DT_CMPL +1).

e. The Value of Z

The value of Z can be either the number of days SE departs the using unit for the Calibration Laboratory/Activity before the expiration of the METR cycle or it can be the number of days equipment departs the using unit after the expiration of the METR cycle. In both cases, the researchers determined Z in the same manner. As previously stated, the researchers organized the MEASURE entries first by part number, then by ECN, and then chronologically by the date the Calibration Laboratory/Activity received the asset (DT_RCVD). The researchers looked for repeating ECNs within a part number and then calculated Z by subtracting the date of the end of the previous METR cycle, plus one day for 67A transport, from the date the calibration facility received the asset (DT_RCVD - (DT_NXT_DUE[of previous cycle] + 1)). The result was the value of Z for that record, specifically, the value Z for that ECN in that specific calibration cycle. If Z was zero, the researchers estimated that the using unit submitted the equipment into the calibration cycle on-schedule. If Z was negative, the researchers estimated that the using unit turned in the equipment “Z” days early. If Z was positive, the researchers estimated the using unit turned in the equipment “Z” days late.

3. Filtering the Data

After the researchers organized the data and assigned formulas to calculate the variables X, Y, Z, V, and W, the researcher's determined the need to "filter" the data. In this project, the term "filter" means the researchers left these records in the data series, but they did not calculate the variable values for these records. The researchers retained these records to maintain continuity in data and ensure they calculated the variables X and Z correctly, since the formulas for X and Z refer to two sequential data records. As a whole, the researchers filtered records that did not follow the typical calibration process, or did not result in the return of equipment back to the using unit. The following sub-sections describe the categories the researchers filtered.

a. Focusing on the North Island Calibration Laboratories/Activities (NIQ and SDB)

Multiple Calibration Laboratories/Activities performed work for HSM-41 and HSL-43 during the period of observation. The researchers focused solely the Calibration Laboratories/Activities at NAS North Island. Examples of other facilities include the calibration shops on-board deployed aircraft carriers or located at foreign base facilities. The researchers filtered out all records where the facilities at North Island (in MEASURE: NIQ or SDB) did not perform the calibration service.

b. Filtering the Equipment Condition Category

The researchers used the Equipment Condition category to determine the condition of the equipment when it arrived at the Calibration Laboratory/Facility. According to the MEASURE manual, the category includes the following four entries.

(1) "1" Entries. The MEASURE manual defines entries of "1" in this category as SE that arrived to the Calibration Laboratory/Activity while still performing within the calibration standards. (DoN, OPNAV OP43P6B, n.d.)

(2) "2" Entries. The MEASURE manual defines entries of "2" in this category as SE that the Calibration Laboratory/Activity serviced because, upon arrival, the equipment did not perform within the standards of calibration. (DoN, OPNAV OP43P6B, n.d.) In these records, the Calibration Laboratory/Activity serviced the

equipment and returned it to the using unit calibrated, with a new METR cycle. Initially, the researchers debated whether or not to include these specific entries in the overall data. The researchers used a 2-sample t-test to determine if these entries were a sub-sample of the original dataset population. The resulting value was a 2.57% chance "Equipment Condition 2" records came from the same population as the "Equipment Condition 1" records. For this reason, the researchers determined not to include the "Equipment Condition 2" records in the final data. The researchers theorized that the sub-custodians recognized the malfunctions in the "Equipment Condition 2" records and did not treat them the same as the "Equipment Condition 1" records. As a result, the researchers filtered the "Equipment Condition 2" records.

(3) "3" Entries. The MEASURE manual defines entries of "3" in this category as SE that the Calibration Laboratory/Activity received in an inoperative status. (DoN, OPNAV OP43P6B, n.d.) The researchers filtered these records because they required non-routine maintenance and deviated from the standard calibration process.

(4) "4" Entries. The MEASURE manual defines entries of "4" in this category as SE that the Calibration Laboratory/Activity received physically damaged. (DoN, OPNAV OP43P6B, n.d.) The researchers filtered these items because they required non-routine maintenance and deviated from the standard calibration process.

c. Filtering the Service Label Category

The researchers used the MEASURE category "Service Label" to identify typical calibrations from non-typical calibration service. The Service Label category includes the following seven possible entries.

(1) Blank Entries. The MEASURE manual, OPNAV OP43P6B, does not define the meaning of blank entries in the Service Label category. The researchers left these records in for continuity in tracking individual serial numbers, but the researchers filtered these records from the final variable values because the purpose of these entries was indeterminate.

(2) “1” Entries. The MEASURE manual defines entries of “1” in the Service Label category as SE upon which the Calibration Activity/Laboratory performed a standard calibration. (DoN, OPNAV OP43P6B, n.d.) The researchers included these entries.

(3) “2” Entries. The MEASURE manual defines entries of “2” in the Service Label category as SE upon which the Calibration Activity/Laboratory performed a special calibration. (DoN, OPNAV OP43P6B, n.d.) The researchers included these entries.

(4) “3” Entries. The MEASURE manual defines entries of “3” in the Service Label category as SE that the Calibration Activity/Laboratory rejected back to the using unit un-calibrated. (DoN, OPNAV OP43P6B, n.d.) The researchers filtered the Service Label entry “3” records because these equipments deviated from the standard calibration cycle for repairs.

(5) “4” Entries. The MEASURE manual defines entries of “4” in the Service Label category as SE that required no calibration action from the Calibration Activity/Laboratory. (DoN, OPNAV OP43P6B, n.d.) The researchers filtered the Service Label “4” records because the Calibration Activity/Laboratory did not assign a value in the “date next due” category.

(6) “5” Entries. The MEASURE manual defines entries of “5” in the Service Label category as SE that the Calibration Activity/Laboratory placed in an inactive status. (DoN, OPNAV OP43P6B, n.d.) The using unit can no longer use these equipments until the facility performs a re-calibration on them. The researchers filtered the Service Label “5” records because these equipments deviated from the standard calibration cycle.

(7) “6” Entries. The MEASURE manual defines entries of “6” in the Service Label category as assets upon which the Calibration Activity/Laboratory repaired the asset without performing calibration procedures. (DoN, OPNAV OP43P6B, n.d.) These actions performed by the Calibration Activity/Laboratory do not alter any

existing cal dates or labels on the equipment. The researchers filtered the Service Label "6" records because they had no affect on the current calibration cycle.

d. Filtering the Work Performed On-Site Category

The category "Work Performed On-Site" delineates whether or not the Calibration Laboratory/Activity performed service on the SE at the using unit's location, or at the laboratory's facility. Entries of "N" indicate work the laboratory completed at their facility. Entries of "Y" indicate work the laboratory completed at the using unit. The researchers filtered the Work Performed On-Site "Y" records because they had no affect on the current calibration cycle.

e. Filtering of Equipment Status

The researchers used the MEASURE category "Equipment Status" to identify how Calibration Activity/Laboratory returned the SE to the using unit. The Label Service category includes the following three possible entries.

(1) "Blank" Entries. Blank entries in the Equipment Status category represent SE that the Calibration Activity/Laboratory returned to the using unit calibrated. The researchers included these entries.

(2) "1" Entries. The MEASURE manual defines entries of "1" in Equipment Status as SE upon which the Calibration Activity/Laboratory deemed too expensive to repair. The researchers filtered the Equipment Status "1" records because these equipments exited the standard calibration cycle.

(3) "2" Entries. The MEASURE manual defines entries of "1" in Equipment Status as SE that the Calibration Activity/Laboratory returned to the using unit un-calibrated. The researchers filtered the Equipment Status "2" records because these equipments exited the standard calibration cycle.

f. Filtering Calculated Values of the Metrology Cycle

The researchers filtered all records where the metrology cycle was less than 61 days. This criterion excluded all records where the metrology cycle was a

negative number due to data entry errors in MEASURE. Additionally, the criterion excluded records that were assigned a metrology cycle that was abnormally small and out of the regular calibration cycle.

F. APPLYING THE SCENARIOS TO THE DATA

The researchers utilized two methods to analyze the data. In the first method, the researcher's analyzed the data as a whole. The researcher's analysis of the entire data set provided the overall process trends and average operational availability. First, the researchers calculated the variable values (X, Y, Z, V, W) for each record. Next, the researchers determined an average value of each variable for both early and late turn-ins. Finally, the researchers calculated the A_i, the Operational Availability without Z and the Operational Availability with Z. The results show the trends for the process inefficiencies as a whole, but do not identify the impact on specific SE. In the second method, the researchers identified the impact on specific SE. First, HSM-41 and HSL-43 identified their 20 most frequently utilized tools and their 10 tools that require the most repeated repairs. The researchers used this information to focus their analysis on these equipments to find the impact of process inefficiencies on operational availability.

The researchers listed the methods they used to calculate the availability reductions in the following sub-sections.

1. Inefficiencies from Early Turn-ins

The researchers defined inefficiencies from early turn-ins as the reduced availability due to the sub-custodian submitting the SE for calibration before the required date next due. The researchers determined that early turn-ins have an affect on operational availability, calibration manpower hours, and equipment value.

a. Reduced Operational Availability

The researchers defined reduced Operational Availability as the percentage of time the tool is not available for use by the sub-custodian because of process inefficiencies versus if those inefficiencies did not exist. To verify the reductions

in availability from early turn-ins, the researchers calculated the operational availability without Z and subtracted the actual availability with the given value of Z. The resulting difference equaled the decrease in operational availability from early turn-ins.

$$\Delta A_O = \frac{X - W}{X + Y + V} - \frac{X - Z - W}{X - Z + Y + V}$$

Equation 9. Reduced Operational Availability from Early Turn-in

The following equation represents a numerical example of the reduced operational availability from early turn-ins. The variable X is a 90-day METR cycle, Y is a 10-day maintenance process, Z is 30 days of early turn in, and V and W are each two days of logistical delay. The resulting Operational Availability follows:

$$\Delta A_O = \frac{90 - 2}{90 + 10 + 2} - \frac{90 - 30 - 2}{90 - 30 + 10 + 2} = 0.057$$

Equation 10. Numerical Example of Reduced Operational Availability from Early Turn-in

The resulting value is a 5.7% reduction in availability from early turn-ins.

b. Additional Calibration Manpower Hours

The MEASURE data defines Calibration Manpower Hours as the hands on time an artisan required to calibrate the SE. (DoN, OPNAV OP43P6B, n.d.) In the researchers' data, the values ranged from 0.2 calibration manpower hours to 24 manpower hours, with a mean of 1.66 hours and a mode of 1 hour. When the sub-custodian turns the equipment in early, the researchers observed that the Calibration Laboratory/Activity must perform additional hours of calibration in the life-cycle of the equipment.

The Navy funds calibration facilities based on forecasted workloads reported by the sub-custodians and data provided by MEASURE. When the Navy

projects its quarterly calibration requirements, it budgets that a calibration facility will calibrate the equipment at the prescribed interval or standard. When the using units turn-in equipment before the end of the METR cycle, they shorten the cycle frequency. As a result, NAVAIRSYSCOM expends additional funding for increased calibration cycles. The overall effect is that the Navy requires additional calibration manpower hours. The researchers determined the additional hours required using the MEASURE data provided by the MOCC.

$$Hours\ Calibrated \times \frac{Z}{X} = Additional\ Hours\ Required$$

Equation 11. Additional Calibration Manpower Hours Required

The following equation represents a numerical example of the additional manpower hours. Assume X is a 90-day METR cycle and Z is 30 days of early turn in. If the actual number of hours used to calibrate the tool is four hours, the resulting additional calibration manpower hours equation is:

$$4\ Hours\ Required\ \ for\ Calibration \times \frac{30}{90} = 1.33\ Additional\ Hours\ Required$$

Equation 12. Numerical Example of Hours Added to Calibration Cycle

The resulting value is 1.33 additional manpower hours required to calibrate the equipment.

c. Additional Manpower Needed for Early Calibrations

In additional to the extra calibration hours the Navy pays for when using units turn assets in early, the Navy must also pay for the additional workforce to handle that workload. According to The Manual of Navy Total Force Manpower Policies and Procedures, the average number of work hours in a week of shore duty is 33.3 hours. (DoN, OPNAVINST 1000.16J, 2002) This equals 1731.6 hours per year (33.3 hours x 52

weeks). The end result is that for every 1731.6 hours additional the Navy needs per year, they need one additional personnel to complete those hours of work. The researchers calculated the number of additional personnel, or fractions of personnel, the Navy needs to complete the calibration work for equipment turned-in early.

d. Unrealized Support Equipment Value

The Navy defines SE availability as the likely hood the equipment is on-hand for use. When a using unit turns in equipment past the METR cycle date, the unit does not have the use of the equipment for all of the additional days. The capability of that equipment is lost and the sub-custodian will not achieve the full usage value of the equipment. For example, assume a tool's value is $1000 with an A_i of 90% and an A_o of 81%. The researchers assume that if a unit achieved 90% availability for this tool, it achieved the full value of this tool. If the availability for the tool was 81%, the reduction in A_o is 9%, but the reduction in tool value is 10%. The following equation illustrates this example:

$$\frac{A_i - A_o}{A_i} = \frac{0.9 - 0.81}{0.9} = 0.1$$

Equation 13. Example Reduction in Equipment Value

The resulting value is 10% in unrealized SE value. If the equipment value was $1,000, the squadron would only realize $900 of value from the equipment.

2. Inefficiencies from Late Turn-ins

The researchers defined inefficiencies from late turn-ins as the reduced availability due to the sub-custodian submitting the SE for calibration days after the required date next due. The researchers determined that late turn-ins have an affect on operational availability and equipment value.

a. *Reduced Operational Availability*

The researchers calculated the reduced operational availability from late turn-ins using the same method described in the early turn-in section. The following equation represents the reduction in operational availability from late turn-ins.

$$\Delta A_O = \frac{X - W}{X + Y + V} - \frac{X - W}{X + Y + V + Z}$$

Equation 14. Reduced Operational Availability From Late Turn-in

The following equation represents a numerical example of the reduced operational availability from late turn-ins. The variable X is a 90-day METR cycle, Y is a 10-day maintenance process, Z is 30 days of late turn in, and V and W are each two days of logistical delay. The resulting Operational Availability follows:

$$\Delta A_O = \frac{90 - 2}{90 + 10 + 2} - \frac{90 - 2}{90 + 10 + 2 + 30} = 0.196$$

Equation 15. Numerical Example of Reduced Operational Availability due to Late Turn-in

The resulting value is 19.6% reduced availability due to late asset turn-in.

b. *Reduced Equipment Value*

The researchers calculated the decreased equipment value from late turn-ins using the same method described in the previous section.

3. Reduction from Process Delays Following Calibration

The last scenario the researchers investigated was the reduction in Operational Availability from the process delays following the calibration of SE. Once the Calibration Laboratory/Activity calibrates equipment, the calibration interval begins, even though the using unit does not have the equipment in its possession. The using unit

losses usable time for the equipment as it processes back to the using unit. The following formula represents the reduction in Operational Availability from the process delays following the calibration of SE.

$$\Delta A_O = \frac{X}{X+Y} - \frac{X-W}{X+Y}$$

Equation 16. Reduced Operational Availability From Process Delays Following Calibration

Assuming X is a 90-day METR cycle, Y is a 10-day maintenance cycle and W is two days of process delay, the resulting Operational Availability follows:

$$\Delta A_O = \frac{90}{90+10} - \frac{90-2}{90+10} = 0.02$$

Equation 17. Numerical Example of Reduced Operational Availability due to Process Delays Folloing Calibration

The resulting value is a 2% loss in Operational Availability from the process delays following the calibration of the equipment.

V. ANALYSIS

A. INTRODUCTION

This chapter contains the researchers' analysis of the data. The first section contains an overview of the data filtering results. The next two sections discuss the overall reductions in A_o, as well as a hypothetical analysis limiting the magnitude of Z. The next section examines the additional calibration manpower hours caused by early turn-ins. The final two sections discuss the overall reductions in A_o for specific SE models, and examine the cost inefficiencies of squadron specific calibration equipment.

B. DATA OVERVIEW

The following table represents an overview of the various data filtering categories and their respective percentage of the total number of usable records. The white rows represent the categories the researchers included in the final data and the shaded rows represent categories of data that the researchers filtered out of the final data.

Data Overview	**Number of Records**	**% of Total**
Total Lines of Data	3,434	100%
Servicing Lab		
NIQ	3,101	90.30%
SDB	118	3.44%
Other	215	6.26%
Equipment Condition		
1	2,582	75.19%
2	467	13.60%
3	256	7.45%
4	129	3.76%
Servicing Label		
Blank	19	0.55%
1	2,799	81.51%
2	119	3.47%
3	382	11.12%
4	50	1.46%
5	1	0.03%
6	64	1.86%

Data Overview	Number of Records	% of Total
Work Performed On Site		
Yes	4	0.12%
No	3,430	99.88%
Equipment Status		
Blank	3,208	93.42%
1	59	1.72%
2	347	10.10%
Metrology Cycles		
> 61 Days	3,363	97.93%
≤ 61 Days	71	2.07%
Overall		
Total Records Filtered	1,141	33.23%
Total Records Used	2,293	66.77%
Repeating Records	1,245	36.26%

Table 1. Data Overview

The filtering was not cumulative from one category to another. For example, the researchers' criteria filtered 516 records out of data in the Service Label category, and their criteria filtered 852 records out of data in the Equipment Condition category, a total of 1,368. When the researchers applied both criteria, a total of 942 records filtered out of the data. This means that 426 records overlapped as records the researchers filtered out of both the Service Label category and the Equipment Condition category. The next six sub-sections detail the individual category filtering statistics and the final section overviews the data filtering as a whole.

1. Servicing Lab

The researchers focused their efforts on the shore based Calibration Laboratory/Activities of NIQ and SDB. These two facilities represent 93.74% of the total calibration workload for the squadrons.

2. Equipment Condition

The researchers focused solely on equipment that entered the Calibration Laboratory/Activity while still within standards. This category amounted to 75% of the

total records. As previously stated, the researchers did not include assets that arrived at the facility broken (Equipment Conditions 3 & 4). Additionally, the researchers excluded assets that arrived out of standard (Equipment Condition 2) because these records did not pass a 2-sample t-test testing if they were from the same population as the Equipment Condition 1 records.

3. Service Label

The researchers focused on records with a Servicing Label value of 1 or 2. Together, these categories amounted to 84.98% of the data for the two squadrons.

4. Work Performed on Site

As stated, this category represents records where the Calibration Laboratory/Activity performed maintenance and servicing at the using unit. The researchers only filtered four records through this category. This category is statistically insignificant in the research.

5. Equipment Status

The researchers only focused on records where the Equipment Status contained a blank value. As a reminder, the blank values represent records where the Calibration Laboratory/Activity returned the asset to the using unit calibrated with a new METR cycle. These records amounted to 93.42% of the total data.

6. Metrology Cycles

The researchers included all records where X calculated greater than 61 days. This criterion included 97.93% of the data. The researchers filtered all values of X less than or equal to 61 because these records were not part of a standard calibration cycle.

7. Summary

Overall, the researchers filtered out 33% of the data. This means that their analysis is pertinent to 66% of the total calibration activity for these squadrons. Of this 66%, slightly more than half of these records (36.26% of the total) were repeat entries for the same serial numbers. The researchers were able to use these records to calculate the values of X and Z and make their recommendations.

C. OVERALL REDUCTIONS IN OPERATIONAL AVAILABILITY

Table 2 illustrates the overall Operational Availability for both of the using units during the entire scope of the data. The table has four columns. The first column represents early turn-ins, the second column represents late turn-ins, the third column represents on-schedule turn-ins, and the final column is an overall analysis taking in the proportion of each of the previous three columns.

The first section of rows in the table outline the number or records of each type of column and lists the average value of each variable (X, Y, Z, V, W). The second section breaks down the A_i, the A_o without Z, and the A_o with Z. For the overall average Operational Availability, the researchers used the proportional average of the first three rows since there is no specific formula that accounts for both positive and negative values of Z.

Overall Operational Availability Chart				
	Early Turn-ins	Late Turn-ins	On-Schedule Turn-ins	Overall
Number of Records (% of total)	793 (63.6%)	426 (34.2%)	28 (2.2%)	1,247
Avg of X in days	460.83	392.52	328.86	435.1
Avg of Y in days	6.52	7.63	4.93	6.86
Avg of Z in days	-153.11	30.51	0	|107.39|
Avg of V in days	3.6	3.37	2.39	3.5
Avg of W in days	3.96	3.31	3.79	3.74

Operational Availabilities				
	Early Turn-ins	Late Turn-ins	On-Schedule Turn-ins	Overall
Inherent Availability (Ai)	.986	.981	.985	.9845
Operational Availability (w/o Z)	.97	.965	.967	.968
Operational Availability (w/ Z)	.956	.897	.967	.936

Table 2. Overall Operational Availability Chart

After analyzing the entire table, the researchers noticed the trends listed in the following sub-sections:

1. Trends in Early versus Late Turn-ins

Given the population of 1,247 entries of repeated serial numbers, the using units turned the items in early 64% of the time and late 34% of the time. The remaining 2% were on-schedule.

2. Trends in the Values of Y, V, W

The values of Y, V, and W remained the same when the researchers examined early, late, and on-time turn-ins independently or, when they examined the data as a whole. In all aspects, the researchers considered the values of Y, V, and W statistically insignificant in the overall affect on A_o because the process causes relatively little delays once the using unit initiates the turn-in of the equipment.

3. Trends in the Values of X

The researchers noticed a general trend in the values of X. The longer the METR cycle, the more likely the using unit turns the SE in early. This trend coincides with the researchers' belief that squadrons may turn-in an asset with a longer METR cycle to have the piece of mind of a current calibration.

4. Trends in the Values of Z

The researchers noticed a distinctive trend in the values of Z in that the magnitude of Z in the early turn-ins is much greater than the magnitude in the late turn-ins.

5. Trends in A_i and A_o

To begin, the researchers calculated the A_i for early, late, and on-tine turn-ins. They observed that all three scenarios had high availabilities due to the relative magnitudes of X and Y. When the researchers calculated the A_os without Z, a slight, uniform reduction occurred across all three scenarios. When the researchers included the variable Z, they noted that the effects of Z on the late turn-ins were more substantial than the effects on the early turn-ins. The researchers determined that the best way to increase the A_o through process change was to limit the magnitude of Z.

D. HYPOTHETICAL ANALYSIS

The researchers recognized two facts after analyzing the data. First, the largest source of inefficiency lays in the using units variable turn-in trends for SE. After the units turn-in equipment, the process is relatively efficient. When compared to the magnitudes of X or Z, the magnitudes of V, W, and Y are relatively small. The second realization is that the Navy cannot expect every unit to turn in every asset on the day the meter cycle expires. Instead, the Navy needs some sort of common sense approach to reduce the variability in turn-in, but allow a reasonable window.

The researchers considered an approach by modeling three scenarios where Z is of no greater magnitude than 7, 10, or 14 days. They recalculated the value of Z, by limiting all values greater than 7, 10, or 14 days equal to their respective limits. The researchers left values smaller than the limit unchanged. Appendix D lists the data for each situation. The A_o changes little when the researchers limit the values of early turn-ins as compared to the changes when the researchers limited the late turn-ins. The researchers considered this fact in their final recommendations.

E. ADDITIONAL MANPOWER HOURS NEEDED FOR EARLY CALIBRATIONS

As previously stated, the researchers identified a metric to define additional calibration man hours needed by the using units. The following table calculates the early turn-ins as a percentage of the overall calibration manpower hours and calculates a dollar value for those additional hours. The researchers multiplied the quantity of additional hours by the average manpower rate for SDB for FY07 of $141.47 per hour. (METCAL, personal communication, October 17, 2006) The table analyzes the entire scope of the useful data since December 2000, the useful data over the past two years, and the useful data over the past year.

	Overall Calibration Manpower Hours	Additional Manpower Hours from Early Turn-ins	Early Turn-in Percent of Overall	Dollar Value of Additional Hours
Since December 2000	6,327.8	344.3	5.44%	$48,708
Past 2 Years	1,900	105.4	5.55%	$14,910
HSM-41	430.2	31.5	7.32%	$4,456
HSL-43	1,469.8	73.9	5.03%	$10,454
Past Year	736.2	38.6	5.28%	$5,497
HSM-41	145.7	7.36	5.05%	$1,041
HSL-43	590.5	31.5	5.33%	$4,456

Table 3. Losses Due to Additional Calibration Man Hours

The end-result was that over a 6-year span, the two units paid for 344.3 additional manpower hours of calibration from early turn-ins. On average, early turn-ins accounted for 5% of the squadron's calibration manpower needs. The Manual of Navy Total Force Manpower Policies and Procedures states that the expected Navy work week in a shore facility as 33.33 hours. (DoN, OPNAVINST 1000.16J, 2000) At this rate multiplied out over 52 weeks, HSM-41 consumes 0.425% of one man year for its additional calibration hours, and HSL-43 consumes 1.819% of one man year for its additional calibration hours.

F. OPERATIONAL AVAILABILITY REDUCTIONS OF SPECIFIC CALIBRATION ASSETS

The following tables illustrate the total percentage of unrealized SE value for two different equipment models. To calculate these values the researchers subtracted the difference between the A_i and A_o with Z. Next, the researchers multiplied this value by the ratio of early turn-ins to total records to calculate the weighted percentage of both early and late turn-ins. The researchers determined the total percentage of unrealized equipment value by adding the results together.

Triaxial Accelerometer					
	A_i	A_o with Z	A_i – A_o w/Z	Weighted % of Total Turn-ins	Total % of Unrealized SE Value
Early Turn-in	.99	.961	.029	1.7%	4.9%
Late Turn-in	.986	.895	.09	3.2%	

Table 4. Unrealized Value in the Triaxial Accelerometer

Single Axis Accelerometer					
	A_i	A_o with Z	A_i – A_o w/Z	Weighted % of Total Turn-ins	Total % of Unrealized SE Value
Early Turn-in	.989	.965	.024	1.7%	5.1%
Late Turn-in	.989	.884	.105	3.4%	

Table 5. Unrealized Value in the Single Axis Accelerometer

Table 4 and Table 5 show that the squadrons do not realize roughly 5% of both equipments' value. This percent difference coincides with the overall change in inherent availability and operational availability with Z from Table 2.

In the analysis of each specific calibration asset, the average early turn-ins impacted the total calibration asset value less than the average late turn-ins. This analysis

supports the researchers' previous findings. The resulting dollar values for the above calculations show relatively insignificant amounts of calibration asset values wasted by the squadrons. The researchers have shown, however, that when squadrons turn in calibration assets late on average they lose a greater amount of the value of the calibration asset.

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VI. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

Initially, the researchers focused on the basic calibration process for support equipment. The researchers determined that the basic calibration process is adequate and that the Intermediate and Depot Level Calibration Laboratories/Activities at NAS, North Island render efficient and successful calibration services that produce in-tolerance support equipment for using units. The basic calibration process comprises two-thirds of the calibration turn-ins. The researchers believe that the source of inefficiencies reside in the one-third of calibration equipment that deviate from the basic process. Calibration equipments that are broken, inoperative or awaiting parts comprise the one-third that departs from the basic calibration process.

The main inefficiencies in the basic calibration process primarily occur from the turn-in habits of the using units. The researchers determined that, over the past 6 years, late and early turn-ins reduced the A_o of SE. Early turn-in of equipment has a 1.1% reduction in A_o, or, the using units received 1.1% reduced availability in the equipment. The researchers also determined that early turn-ins ultimately result in roughly a 5% increase in equipment calibration/servicing during the life cycle of the equipment, thereby increasing the life cycle costs. Late turn-ins also have an effect on A_o. The researchers determined that late turn-ins reduced the A_o by 3.4%. Although both early and late turn-ins had negative effects on the A_o, the researchers believe that these process inefficiencies do not have a significant effect on fleet operational readiness.

B. RECOMMENDATIONS

1. Limit Turn-In Inefficiencies Through Policy Change

As noted in Appendix D, the A_o only changed slightly when the researchers implemented hypothetical limits for late and early turn-ins. By promoting a policy change for calibration turn-ins within plus or minus 14 days from the due date, the increase in A_o would range from 1% to 5%. The Navy can implement the policy by

electronically updating the MEASURE 802 format daily and providing visibility of this report to all entities in the calibration cycle.

An example policy change would be if the using units turned in SE no greater than 14 days early. The following table displays the resulting changes in A_o.

Overall Operational Availability Chart				
	Early Turn Ins	**Late Turn Ins**	**Zeros**	**Whole**
Records	793	426	28	1247
X	460.83	392.52	328.86	435.1
Y	6.52	7.63	4.93	6.86
Z	**-11.08**	30.51	0	**|17.47|**
V	3.6	3.37	2.39	3.5
W	3.96	3.31	3.79	3.74
Ai	0.986	0.981	0.985	0.984
Ao no Z	0.970	0.965	0.967	0.968
Ao w/Z	**0.969**	0.943	0.967	**0.945**

Table 6. Regulation of Z for Early Turn-ins

As a result of the suggested changes, the overall A_o increases from 93.4% (See Table 2) to 94.5%. The researchers determined this percentage increase by limiting the early turn-in variable "Z" to 14 days while allowing all other variables and late turn-ins to remain the same.

Another example of a policy change would be if the using units turned in SE no greater than 14 days late. The following table displays the resulting changes in A_o.

Overall Operational Availability Chart				
	Early Turn Ins	**Late Turn Ins**	**Zeros**	**Whole**
Records	793	426	28	1247
X	460.83	392.52	328.86	435.1
Y	6.52	7.63	4.93	6.86
Z	-153.1	**9.31**	0	**|100.5|**
V	3.6	3.37	2.39	3.5
W	3.96	3.31	3.79	3.74
Ai	0.986	0.981	0.985	0.984
Ao no Z	0.970	0.965	0.967	0.968
Ao w/Z	0.956	**0.943**	0.967	**0.952**

Table 7. Regulation of Z for Late Turn-ins

With the regulation of late turn-ins, the overall A_o would increase from 93.4% to 95.2%. The researchers determined this percentage increase by limiting the late turn-in variable "Z" to 14 days while allowing all other variables and early turn-ins to remain the same.

The final example combines the previous policy changes and simulates the using units turning in SE no greater than 14 days early or late. The following table displays the resulting changes in A_o.

Overall Operational Availability Chart				
	Early Turn Ins	**Late Turn Ins**	**Zeros**	**Whole**
Records	793	426	28	1247
X	460.83	392.52	328.86	435.1
Y	6.52	7.63	4.93	6.86
Z	**-11.08**	**9.31**	0	**|10.22|**
V	3.6	3.37	2.39	3.5
W	3.96	3.31	3.79	3.74
Ai	0.986	0.981	0.985	0.984
Ao no Z	0.970	0.965	0.967	0.968
Ao w/Z	0.969	0.943	0.967	**0.960**

Table 8. No Z Greater than 14 Days for Late and Early Turn-ins

By regulating Z to less than 14 days in magnitude, the overall A_o would increase from 93.6% to 96%. The researchers determined this percentage increase by reducing both variables of "Z" to 14, while allowing all other variables to remain the same. The increases in A_o only represent changes for the 2,293 usable records, or two-thirds of the data population. If the 2.4% difference holds true for all items, the Navy has the potential to recapture at least 1.6% of its capital investment value in calibration support equipment across the entire Navy.

2. Change the Navy's Method of Assigning METR Cycles

The researchers investigated whether or not the Navy could change the way it assigns the METR cycles. According to NAVAIR 17-35TR5, the Navy based its assignment of METR cycles upon an agreement between the Navy Systems Commands

and METCAL. The Navy created the cycles to ensure an 85% End of Period reliability for critical test equipment and 72% End of Period reliability for all other test equipment. With these criteria, the Navy looks at each calibration asset as if they field it independently; however, the using units usually possess multiples of each asset. If the Navy considered this fact, it might be able to increase the METR cycle lengths due to the fact the assets essentially work in parallel. For example, consider the following figures. The first figure displays the reliability of a single tool to be 85%.

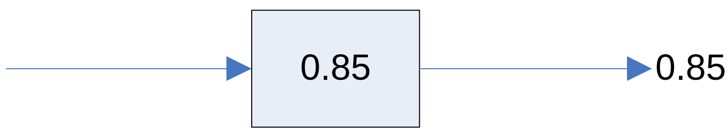

Figure 9. Reliability of a Single Calibration Asset Considered Independently

The next figure displays the same asset, but considers the mission reliability if the using unit possess five on hand.

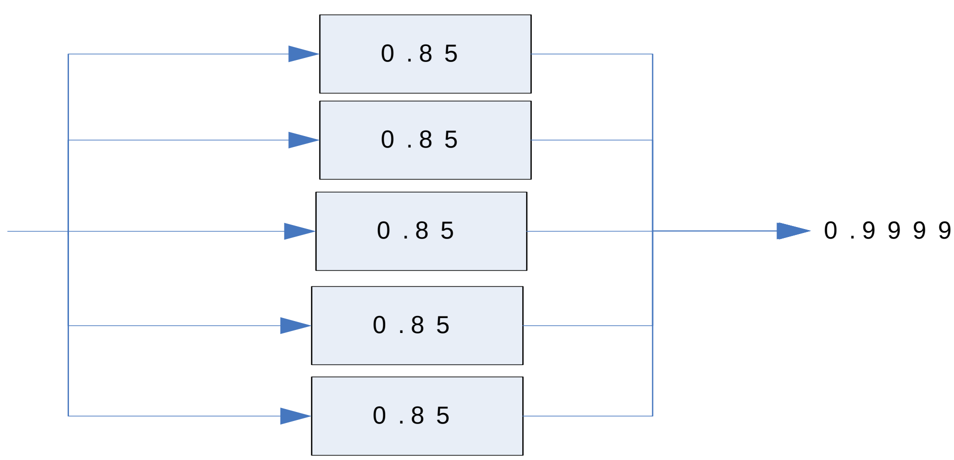

Figure 10. Reliability of Multiple Calibration Assets Considered in Parallel

The resulting reliability is 99.99% because the Navy considers the asset's reliability in parallel. In this specific scenario, the individual asset reliabilities could

decrease to 37%, but the reliability of all five in parallel, or the chances that one asset remains within calibration standards, is 90%. While this new method is attractive mathematically, it is not practical. First, the number of like assets in a unit increases or decreases depending on whether or not the squadron deploys as a whole unit or as detachments. Thus, the number of assets in parallel depends on how the squadron deploys. Additionally, this method assumes that the using units recognize which assets are within standards and which assets are out of standard. The researchers did determine that the using units' turn-in habits are different between equipment out of calibration and equipment in calibration. What is not clear is how reliably using units differentiate between broken and inoperative equipment. If the Navy wanted to extend the METR cycles based on this philosophy, it would depend on the units' ability to visually recognize which equipments remain within standards and only use those equipments. This method presented a potential catastrophic safety risk and the researchers determined this method was not a viable recommendation.

3. Implementation of Information Technology Systems

The researchers also considered the implementation of advanced information technology systems to assist with monitoring and tracking SE. One of the concerns from the using units was the inability to view the status and location of equipment as it transitioned through the calibration cycle.

The implementation of an advanced web-based information technology system that links with MEASURE is capable of providing all entities in the calibration cycle with real-time information to facilitate adequate resource planning. These types of tracking solutions are currently being investigated by the Marine Corps through an initiative called Marine Air-Ground Task Force (MAGTF) Distribution. The purpose of this initiative is to:

- Enable visibility across the distribution chain. (United States Marine Corps [USMC], 2006)
- Establish roles and responsibilities for managing MAGTF distribution capabilities. (USMC, 2006)

- Achieve centralized control of the MAGTF distribution chain. (USMC, 2006)
- Initiate and integrate people, processes, and technologies via new doctrine, organizations, training, and material solutions. (USMC, 2006)

The implementation and integration of this type of information technology system for the calibration cycle would involve creating a new software package to capture the data, training personnel on the new system and providing support personnel to maintain the system. Although this option could provide total asset visibility and increased information for planning purposes, the researchers decided that this option would be too cost intensive to justify the returns.

C. FURTHER STUDY

Beyond the submission of recommendations, the researchers also determined that the Navy could conduct further investigation of the following subjects to provide more information on how to make the calibration process more efficient for increased unit readiness.

1. Increase the Length of Metrology Intervals

OPNAV OP43P6B defines metrology intervals as the maximum interval, or number of months, a specific item of equipment, may stay in service before it requires calibration or servicing from a Calibration Laboratory/Activity. (DoN, OPNAV OP43P6B, n.d.) NWSC creates and monitors these intervals with uniform and traceable links to the NIST, U.S. Naval Observatory, or DoD approved calibration facilities. As the researchers reviewed the MEASURE data, they noticed that out of the 3,434 lines of data, 2,582 contained an Equipment Condition code of 1.

According to OPNAV OP43P6B, an Equipment Condition code of 1 means that during calibration, the equipment performed to specifications without adjustments. (DoN, OPNAV OP43P6B, n.d.) Further research on this topic would possibly save on funding and man-power requirements, while also slightly increasing equipment A_o.

2. Work Center 67A

One of the difficult aspects of the research was determining the actual cycle time of SE at Work Center 67A. As discussed in Chapter II, personnel from Work Center 67A pick up the equipment and take it directly to the Calibration Laboratory/Activity. After the laboratory calibrates the equipment, the 67A personnel pick up the equipment, sort it, and return it to the using unit. Although work center managers claim the cycle time at the facility is one day, some using unit personnel claim that some equipment remains in the work center longer. Further research on this topic could lead to a reduction in turn-around time and increased equipment A_o.

3. Monitor Support Equipment Throughout the Calibration Process

Currently, MEASURE tracks SE at the Calibration Laboratory/Activity. While MEASURE is ideal for tracking equipment activity within the Calibration Laboratory/Activity, it does not track equipment movement and activity outside of the facility. If the Navy extended MEASURE to include all entities within the calibration process, it could properly track turnaround time by maintaining accountability and asset visibility.

4. Calibration Support Equipment Repair and Maintenance Process

When the researchers first interviewed using unit personnel at North Island, most viewed the calibration process as inefficient and lengthy. Through an in-depth analysis of the standard calibration process, the researchers determined the process to be efficient. It is important to note that the scope of the research did not include broken or inoperable equipment. Further research may determine that the frustrations of using units may lie in the repair and maintenance aspects of the calibration processes, and the ages of the SE.

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APPENDIX A. MEASURE FORMAT 802

DATE PRINTED: 03/28/90

METROLOGY AUTOMATED SYSTEM FOR UNIFORM RECALL AND REPORTING

PAGE NO. 1

MEASURE FORMAT 802
(IN-LAB ONLY)
INVENTORY TEST EQUIPMENT DUE FOR CALIBRATION DURING THE PERIOD: 04/01/90 THRU 06/30/90
SEQUENCED BY CUSTOMER, SUBCUSTODIAN, NEXT DUE DATE, MODEL NUMBER, CAL LAB

CUSTOMER (AIMDMMA)
SUBCUSTODIAN (FUELS)

LINE NO.	LAB	SHOP NO.	NEXT DUE DATE	MODEL/PART NO.	MFR	SERIAL NUMBER	NOMENCLATURE	PART OF	MET CYC	S T D	IIC	STD HOURS	EQPT CTL NUMBER
0001	MGQ		050990	0-300PSI	61349	199-013	PRESSURE GAGE		12	N		.9	WES1680214
0002	MGQ		051190	0-100PSI	61349	199-91	PRESSURE GAGE		12	N		1.0	WES1392775
0003	MGQ		051190	0-200PSI	61349	199-43	PRESSURE GAGE		12	N		1.0	WES1371732
0004	MGQ		051290	0-150PSI	61349	199-33	PRESSURE GAGE		12	N		.9	WES1685998
0005	MGQ		051290	0-200PSI	61349	199-35	PRESSURE GAGE		12	N		1.0	WES1684712
0006	MGQ		051290	0-300PSI	61349	199-36	PRESSURE GAGE		12	N		.9	WES1371777
0007	MGQ		051590	0-100PSI	61349	199-103	PRESSURE GAGE		12	N		1.0	WES1392833
0008	MGQ		051590	0-100PSI	61349	199-107	PRESSURE GAGE		12	N		1.0	WES1392851
0009	MGQ		051590	0-100PSI	61349	199-79	PRESSURE GAGE		12	N	WES1	1.0	WES1392692
0010	MGQ		051590	0-200PSI	61349	199-37	PRESSURE GAGE		12	N		1.0	WES1371712

(FUELS) TOTAL STD HRS: 9.7
TOTAL ITEMS: 10

Figure J-17. Example of MEASURE Format 802 (In-Lab Due).
(Page 2 of 5)

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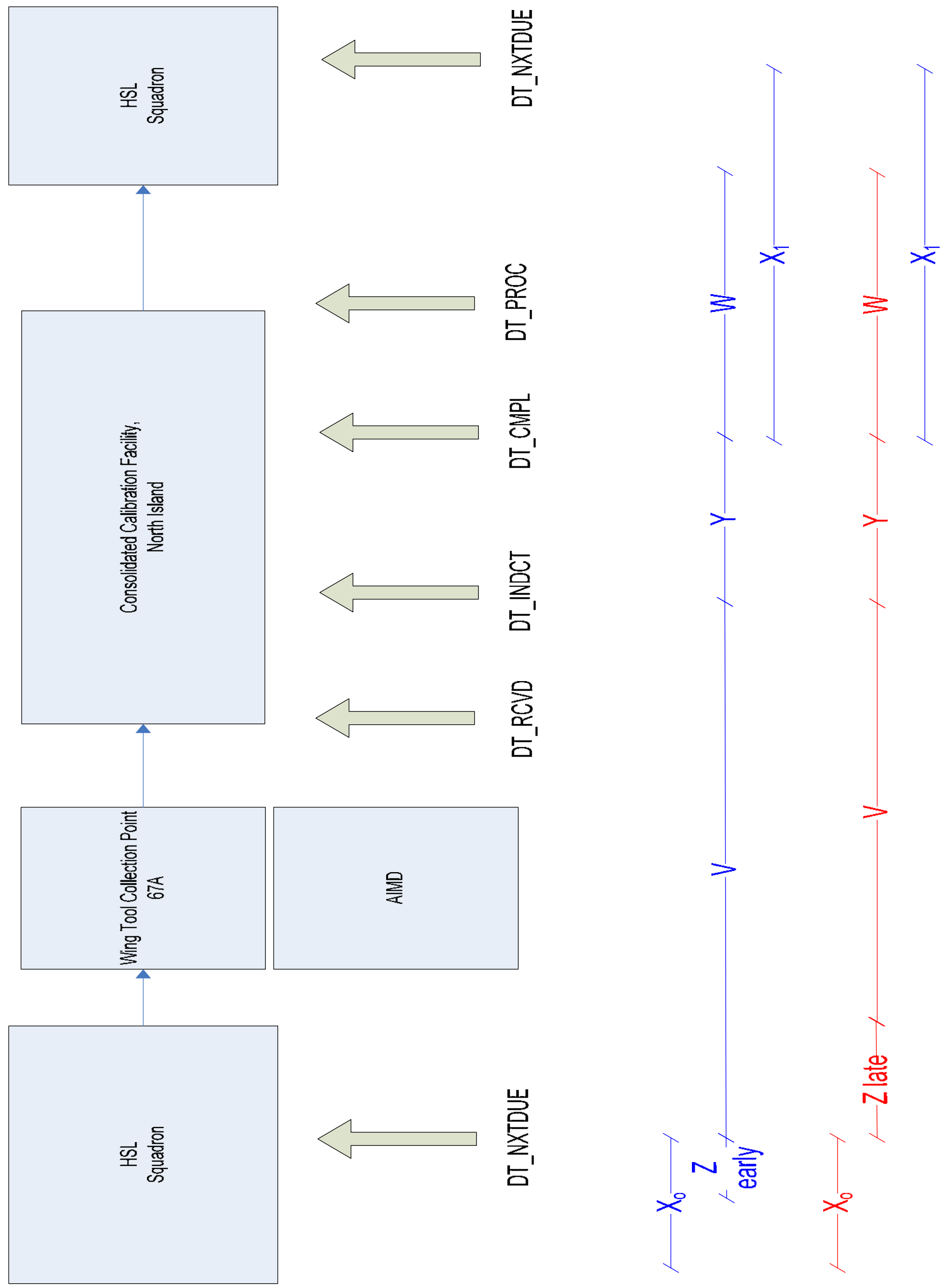
APPENDIX B. CALIBRATION CYCLE



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APPENDIX C. HYPOTHETICAL TURN-IN ANALYSIS

	Early Turn-ins			Late Turn-ins		
	No Z > 7 Days	No Z > 10 Days	No Z > 14 Days	No Z > 7 Days	No Z > 10 Days	No Z > 14 Days
Number of Records	793	793	793	426	426	426
Avg of X (days)	460.83	460.83	460.83	392.52	392.52	392.52
Avg of Y (days)	6.52	6.52	6.52	7.63	7.63	7.63
Avg of Z (days)	-6.15	-8.36	-11.08	5.76	7.49	9.31
Avg of V (days)	3.6	3.6	3.6	3.37	3.37	3.37
Avg of W (days)	3.96	3.96	3.96	3.31	3.31	3.31
	Early Turn-ins			Late Turn-ins		
	No Z > 7 Days	No Z > 10 Days	No Z > 14 Days	No Z > 7 Days	No Z > 10 Days	No Z > 14 Days
Inherent Availability (Ai)	0.986	0.986	.0986	0.981	0.981	0.981
Operational Availability without Z	0.970	0.970	0.970	0.965	0.965	0.965
Operational Availability with Z	0.9697	0.9696	0.9693	0.951	0.9469	0.9428

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